RESEARCH DEPARTMENT

THE INFLUENCE OF LISTENING CONDITIONS ON THE QUALITY OF REPRODUCED SPEECH

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INTRODUCTION

Recent work on talks studios has shown that the quality of reproduced speech is more dependent upon the acoustics of the listening room than has hitherto been realised. Thus, the speech is likely to have bass colouration when heard in a room with excessive low-frequency reverberation, whatever the studio from which it originates, while it will often tend to "jangle" and sound harsh if reproduced in an acoustically dead room.

The ultimate criterion of success in the design of a studio is the quality obtained by the listener in his own living room, and it is thus essential that the nature and extent of these variations of quality with listening conditions should be known. This report describes two series of experiments conducted to answer the following questions:

1. To what extent does the order of preference in which a listener places a number of studios depend upon the listening conditions?

2. Can the preference order be considered constant over the normal range of home listening conditions?

3. Is there sufficient acoustic similarity between B.B.C. listening rooms and control cubicles on the one hand and domestic listening rooms on the other?

4. How far is it profitable to pursue the elimination of colouration in talks studios before the improvement is masked by listening room colourations?

This report is divided into two parts. Part I is concerned with the effect of listening conditions on listeners' preferences. Part II describes an acoustic survey of a number of domestic listening rooms.

PART I

RANKING TESTS ON STUDIOS

1. METHOD.

Recordings made from six talks studios were played under four different listening conditions to a panel of engineers. The method of paired comparisons was used, whereby the subject is presented in turn with each of the possible pairs selected from the objects to be ranked and asked to state a preference in each case. In the present case, with six studios, there are 15 paired comparisons, each studio being compared with each of the five others. If a mark is awarded to a studio for each comparison in which it is preferred, then in any set of 15 pairs the six studios should score respectively 5, 4, 3, 2, 1 and 0 marks, thus yielding a ranking order.

If, however, a subject's voting shows that, while preferring A to B and B to C, he nevertheless prefers C to A, then all three studios will score the same number of marks, and there will be a tied place in the ranking order. The maximum number of these "inconsistent triads" which can occur with six objects is eight, and in the present experiment the number (denoted by the symbol t) varied from zero to seven. Poor consistency may be obtained either because the subject cannot detect appreciable differences between the studios or because the overall merit is compounded from several factors present in varying proportions in the different studios.

In order to avoid irrelevant differences between tests the same voice reading the same passage of about one minute's duration was used throughout. For each of the 15 successive paired comparisons the passage was heard from start to finish, the first and last thirds coming from one studio and the middle third from another. Subjects thus heard the transition from one studio to the other in both senses.

The order of presentation of the 15 pairs was different for each listening room thus preventing subjects from memorising the sequence and their previous results.

2. EXPERIMENTAL DETAILS.

The studios and listening rooms used were as follows:

Studio A Narrator's studio, Studio No. 8 Broadcasting House
B Narrator's studio, Studio No. 6A Broadcasting House
C Studio No. 3B Broadcasting House
D Studio No. 3G, Egton House (Home News Studio)
E Experimental Talks Studio, Nightingale Square, (Diesel House Studio)
F Non-reverberant room, Kingswood Warren.

Listening Room a Quality Listening Room (No. G.16 Nightingale Square)
b. Acoustic Tent in Experimental Studio No. G.12 Nightingale Square
c Untreated Office (No. 110 Nightingale Square)
d Experimental Studio No. G.12 without acoustic tent.

The listening rooms were used in the order given above. A final set of tests in Listening Room a confirmed that observers' preference had not significantly changed during the experiment.

Ribbon microphones, type AXBT, were used throughout, at 2 ft for Studios A to E and at 3 ft for F. Each of the four operational studios was recorded through the usual studio circuit, including any bass cuts. Studio E was given a typical operational bass cut circuit ($4\mu F$ shunted by $4{\cdot}7\,k\Omega$ in each leg of the microphone circuit) and Studio F a circuit which compensated for the 3 ft working distance.

Figs. 1 and 2 give the reverberation curves of Studios A to E and Rooms a, c and d respectively. Listening Room b is taken as acoustically dead, for although the effect of the acoustic tent is only to give an attenuation of reverberant sound

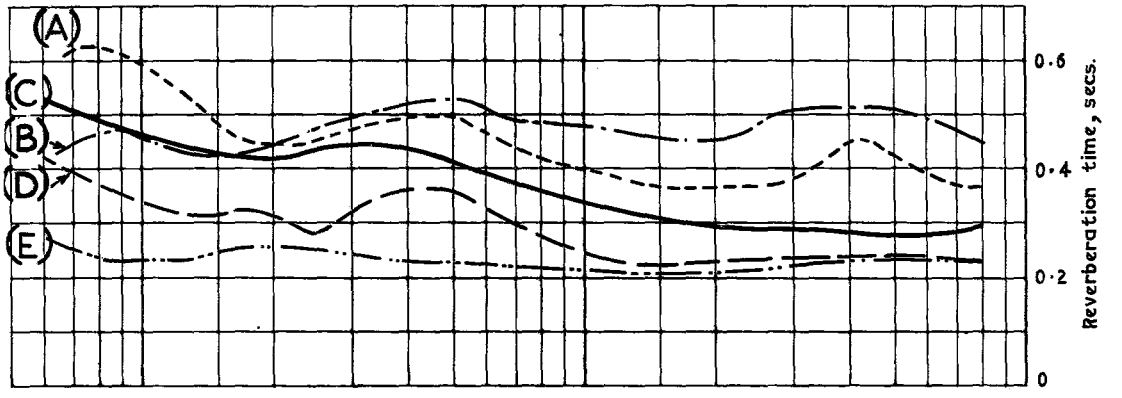

Fig. 1. Reverberation characteristics of studios used in ranking tests.

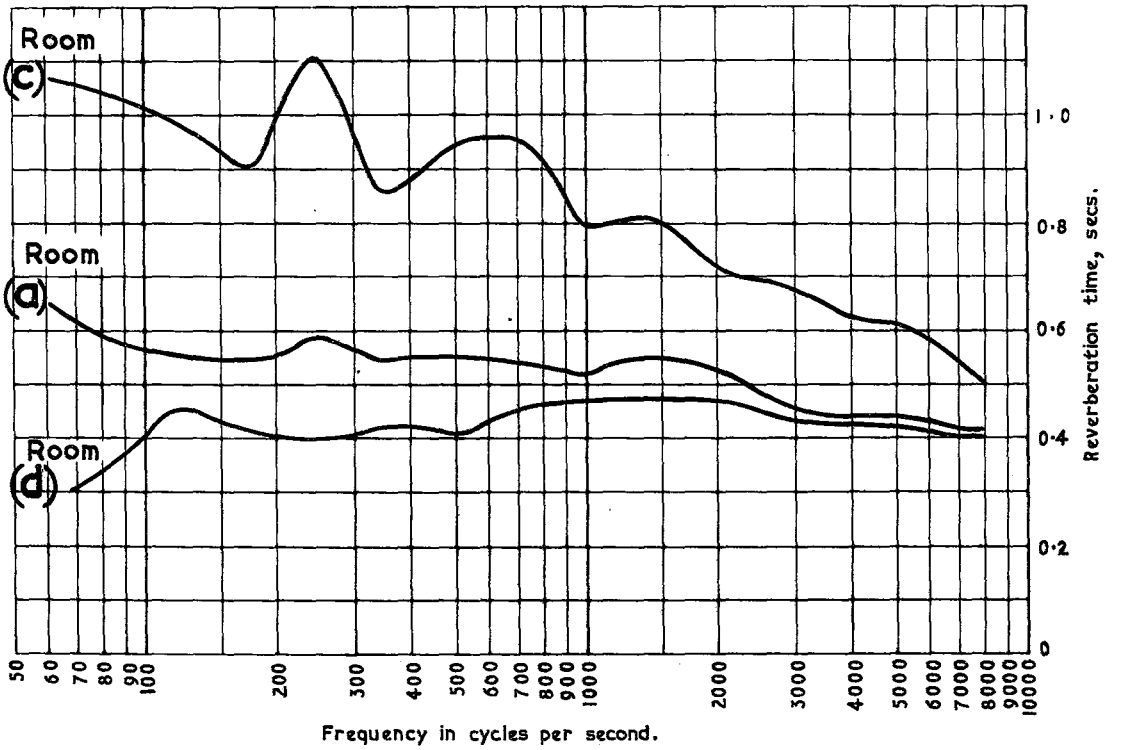

Fig. 2. Reverberation characteristics of listening rooms used in ranking tests.

Listening Room	Mean t
a	0·56
b	1·33
c	1·45
d	0·86
a(repeat)	0·50

When the experiment was planned it was expected that Listening Room b, approximating to dead conditions, would enable studios to be judged with the maximum of ease and consistency. In fact, although the distinctions between studios are indeed most clearly recognizable in this room, it is very difficult to express them in the form of a preference, as is shown by the high mean value of t. In a more reverberant room (a or d) the preference rests largely with the relative extent to which the two studios accentuate or ameliorate the outstanding faults of the listening room (usually excessive bass reverberation) and a higher degree of consistency is obtained. In an excessively reverberant room such as c, the distinction between studios is largely masked by listening room colouration, as is shown by the high value of t. Nevertheless, there is in this listening room an unmistakable preference for Studio C which is the only studio tested having a heavy bass cut.

4. CONCLUSIONS.

The subjective ranking order of speech studios is unlikely to be affected seriously by any normal fluctuation in listening room acoustics. The absolute quality of speech will suffer, however, if the room is too reverberant, as will the observer's ability to discern subtle differences in studio acoustics. Dead conditions are to be recommended for diagnostic listening, but are too oppressive for general use, give unwelcome prominence to middle and upper frequency studio acoustics and confuse observers seeking only ranking orders.

A by-product of the experiment was the ranking order of the six studios used. This showed that Studio E, with a sensibly flat reverberation characteristic of about 0·25 sec most nearly meets with general approval and that very live studios such as A and B are rejected under all listening conditions. The experiment also showed that, within the small group of engineers taking part, opinion is evenly divided on the merits of a completely dead studio relative to a good operational studio; this shows that the absence of colouration does not of itself ensure pleasing speech quality.

The method of ranking by paired comparisons could be used with advantage in the subjective assessment of new speech studios, despite certain practical difficulties. If a new studio were included among a number of standard studios of suitably graded quality, it could be presented anonymously to a panel of listeners. They would then assign it a definite ranking in terms of known quantities, independent of the precise listening conditions and their own recent listening history, and free from the prejudices inseparable from prior knowledge of the size, reverberation characteristic and appearance of the studio.

PART II

SURVEY OF DOMESTIC LISTENING ROOMS

1. EXPERIMENTAL PROCEDURE.

Reverberation characteristics were measured in 16 domestic listening rooms in the homes of members of the department and their friends, and listening tests were carried out in 13 of these rooms. The rooms differ widely in size, date of building and furnishing and are taken to represent typical present day listening conditions among middle-class listeners in the Greater London area.

The test material consisted of passages of speech recorded from the non-reverberant room at Kingswood Warren and from a number of talks studios. The recordings were played over a wide range loudspeaker to a panel of engineers and a qualitative assessment was made of the colouration added by the listening room to the "dead" speech, and the ease with which the characteristics of different studios could be distinguished.

2. RESULTS.

Fig. 3(a) shows the mean reverberation times of the 16 rooms measured. Separate analysis of the 11 pre-war and 5 post-war rooms does not give any appreciable difference in reverberation time, except at 125 c/s and 175 c/s, where the post-war rooms are 0·05 sec higher. Since post-war building methods give walls, floors and ceilings of comparatively low absorption coefficient, particularly at low frequencies, this similarity of reverberation time is probably due to the smaller volume of the newer rooms, and the large proportion of the absorption provided by furnishings.

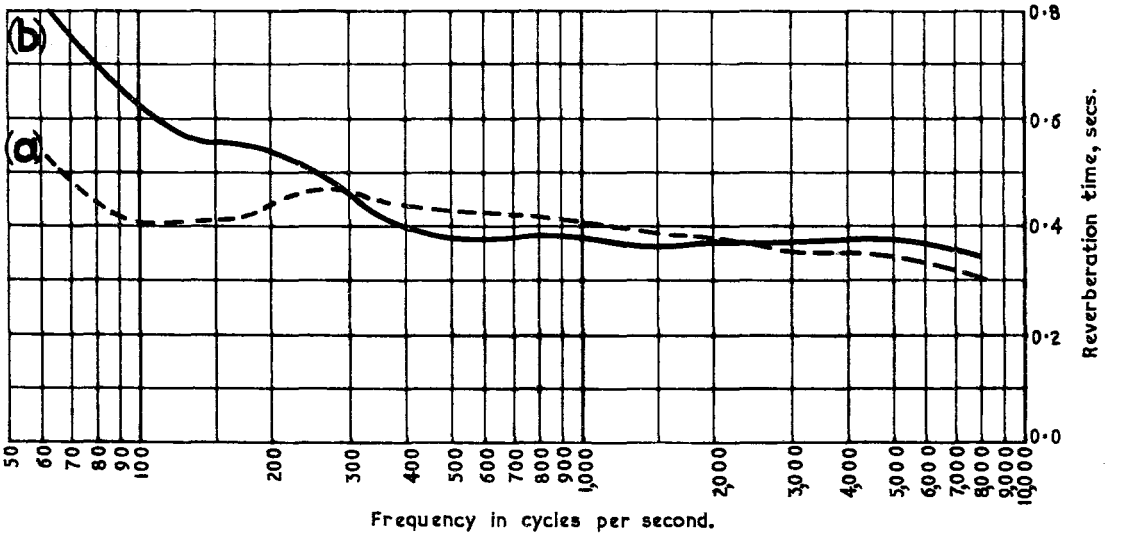

Fig. 3. Mean reverberation characteristics of:
(a) 16 domestic listening rooms
(b) 16 post war studio control cubicles.

Fig. 3(b) shows the mean reverberation times of 16 studio control cubicles, chiefly from the studio centres at 1a, Portland Place and Belfast, all re-treated since the war. It will be seen that while the agreement between the two curves is quite close above 250 c/s, the bass rise of the control cubicles is much greater than that of the domestic listening rooms.

The listening tests showed that the domestic rooms varied from the completely satisfactory to those which produced heavy colouration, even on "dead" speech. A reverberation time of about 0·4 sec may be taken as critical; above this value the listening room reverberation becomes obtrusive, although in none of the rooms visited was the effect so great as completely to mask the distinction between good studios and bad.

3. CONCLUSIONS.

The domestic listening rooms encountered lie within the range of listening conditions for which the ranking order of studios is found to be constant and for which it may readily be assessed. It is therefore unlikely that the faults of studios will be reduced to proportions negligible in comparison with listening room colourations. The reverberation characteristic of the Nightingale Square Listening Room No. G.16 (Fig. 2) is too high to be typical of domestic listening conditions, although it is comparatively level. So that Research Department results might be acceptable to outside and non-technical bodies, it has hitherto been thought preferable for the listening room to be untreated and Room No. G.16 has, for this reason, been allowed to remain in its present rather live condition for a number of years. This discrepancy of reverberation time makes little or no difference to the reproduction of music but as has been shown, it is important in the case of speech. It has, therefore, been decided to reduce the reverberation time to 0·4 sec, falling to 0·3 between 1 kc/s and 8 kc/s, to achieve better reproduction of speech and a more typically domestic reverberation characteristic.

The excessive bass reverberation of studio control cubicles is most unsatisfactory, and little improvement in speech quality can be expected from the installation of wide range loudspeakers so long as they are placed in surroundings acoustically inferior to normal domestic living rooms. Indeed, in some cubicles it has been found that such a loudspeaker can be made usable only by considerable attenuation of its low frequency response.